



Test Case Baseline Results

5th Ablation Workshop

Ablation Test-Case Series #2

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Objective



- Present baseline test cases using CMA & FIAT for Mutation generated surface thermochemical (B') tables using CEA database
 - Problem 2.1 – Low heat flux in-depth pyrolysis only case
 - Problem 2.2 – Low heat flux surface ablating case
 - Problem 2.3 – High heat flux surface ablating case
- Present results for other, alternative thermochemical models
 - CEA database generated by ACE (25 gas species)
 - JANAF 88 database generated by ACE (23 gas species)
 - JANAF 88 database plus Livermore Carbon data (25 gas species)



Surface Equilibrium/Non-equilibrium Codes



- Mutation
 - 2011 code
 - Stagnation line formulation
 - Uses CEA data

- Aerotherm Chemical Equilibrium (ACE)
 - 1990's version code
 - Versatile multi-species equilibrium/non-equilibrium surface
 - Modified to use both JANAF and CEA thermodynamic data



In-Depth Material Response Codes



- Charring Material Ablator (CMA) 87S
 - 1990's version code
 - Decoupled surface energy balance and in-depth decomposition
 - Modified from original version to include implicit pyrolysis gas
- Fully Implicit Ablation and Thermal response (FIAT) 3.0
 - Modern day successor of CMA
 - Fully implicit algorithm (except for radiation term)



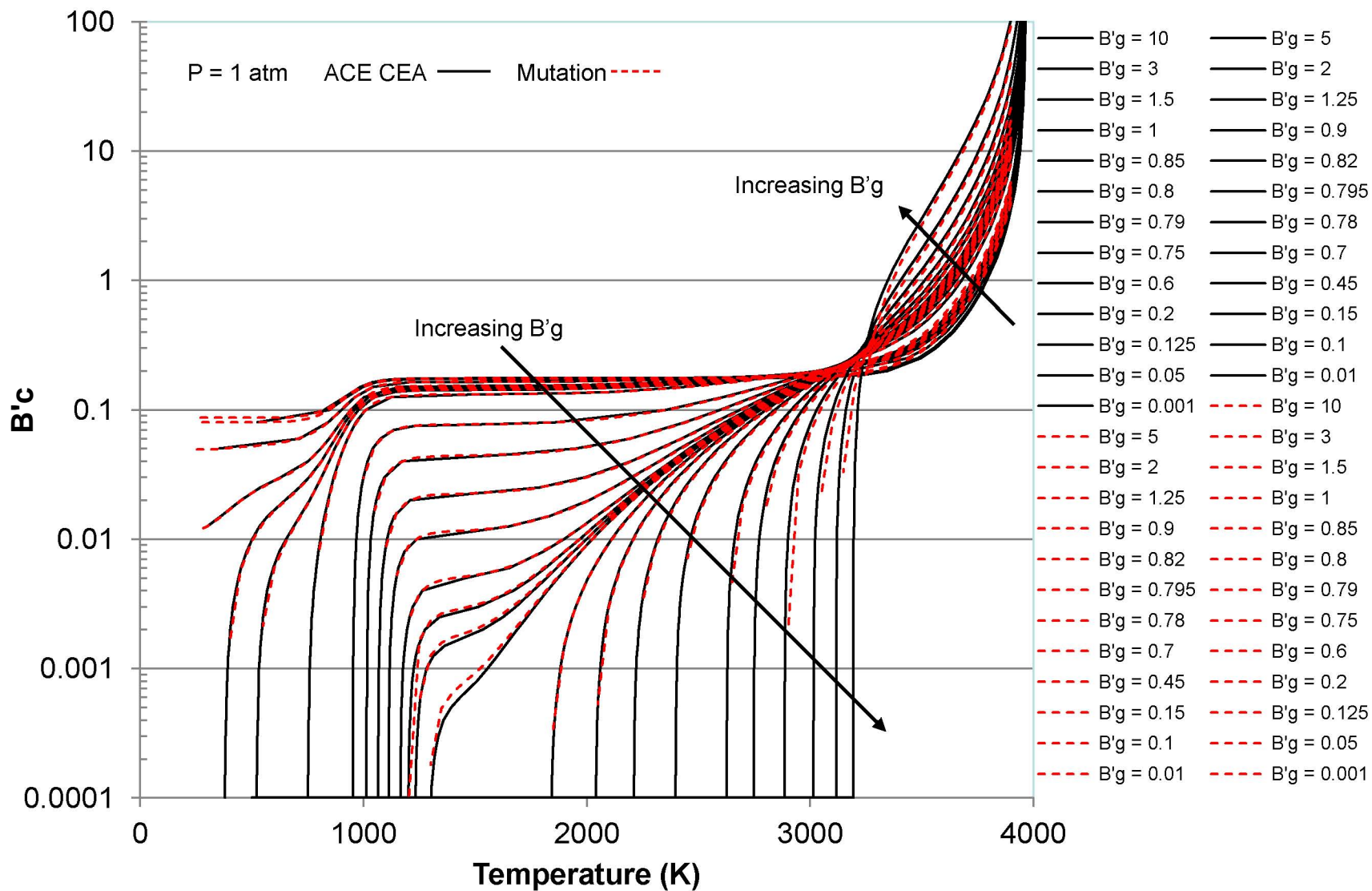
Thermochemistry Models



- Mutation CEA
 - 25 gas phase species and graphite from CEA database
 - C, H, O, N, CH₄, CN, CO, CO₂, C₂, C₂H, C₂H₂, acetylene, C₃, C₄, C₄H₂, butadiene, C₅, HCN, H₂, H₂O, N₂, CH₂OH, CNN, CNC, CNCOCN, C₆H₆, & HNC, plus graphite C(gr)
 - Note, for FIAT comparison, only a subset of the table at 100 K increments was used
- ACE CEA
 - Same 25 gas phase species and graphite from CEA database
- ACE JANAF
 - 23 gas phase species (no CNCOCN & CH₂OH) and solid carbon from JANAF 88 database
- ACE JANAF – Livermore
 - 25 gas phase species total: 18 gas phase species from JANAF 88 database (no C₁ through C₅) plus 7 gas phase carbon species (C₁ through C₇) and solid carbon from Livermore data.

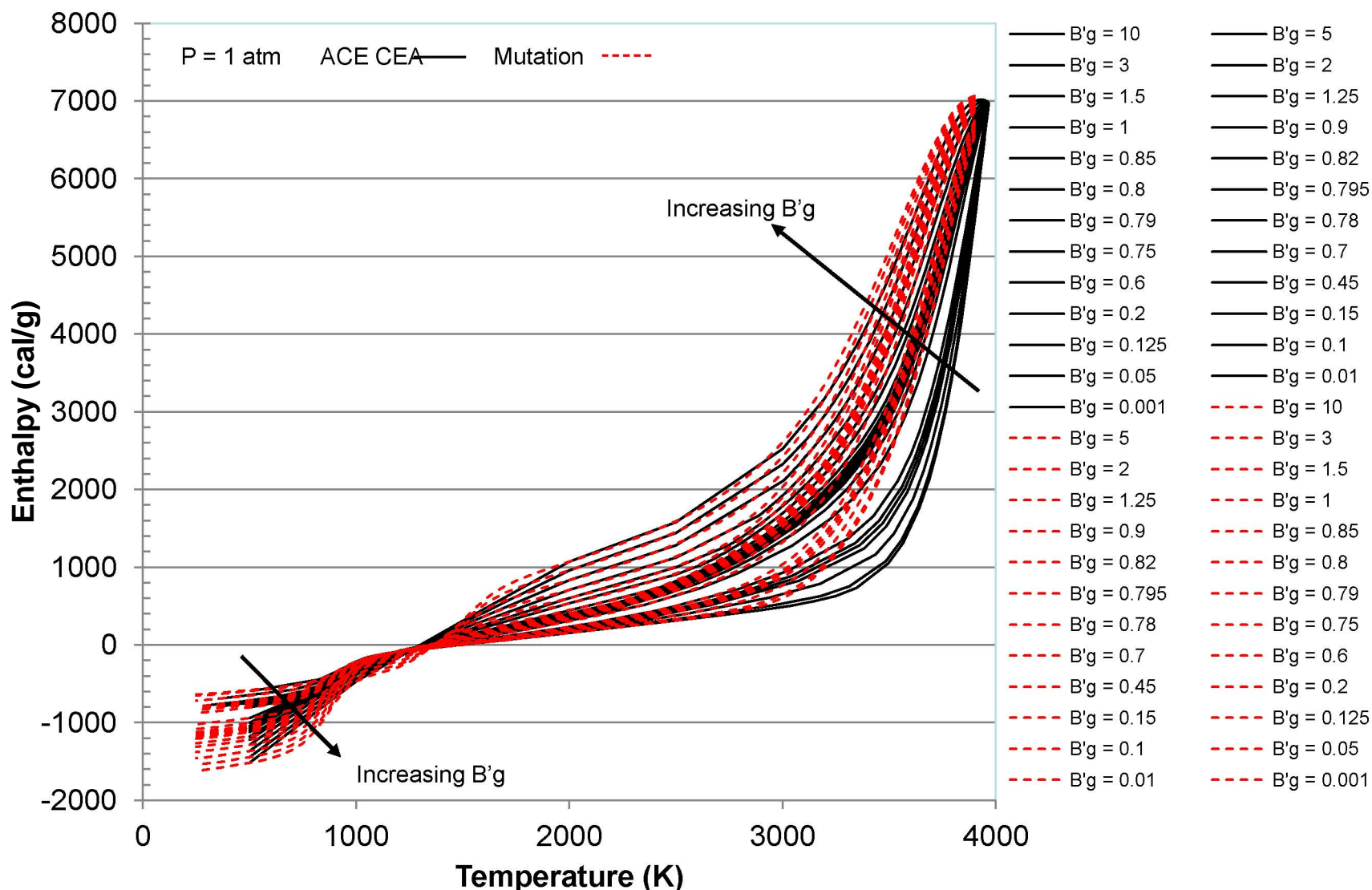


Mutation CEA versus ACE CEA - I



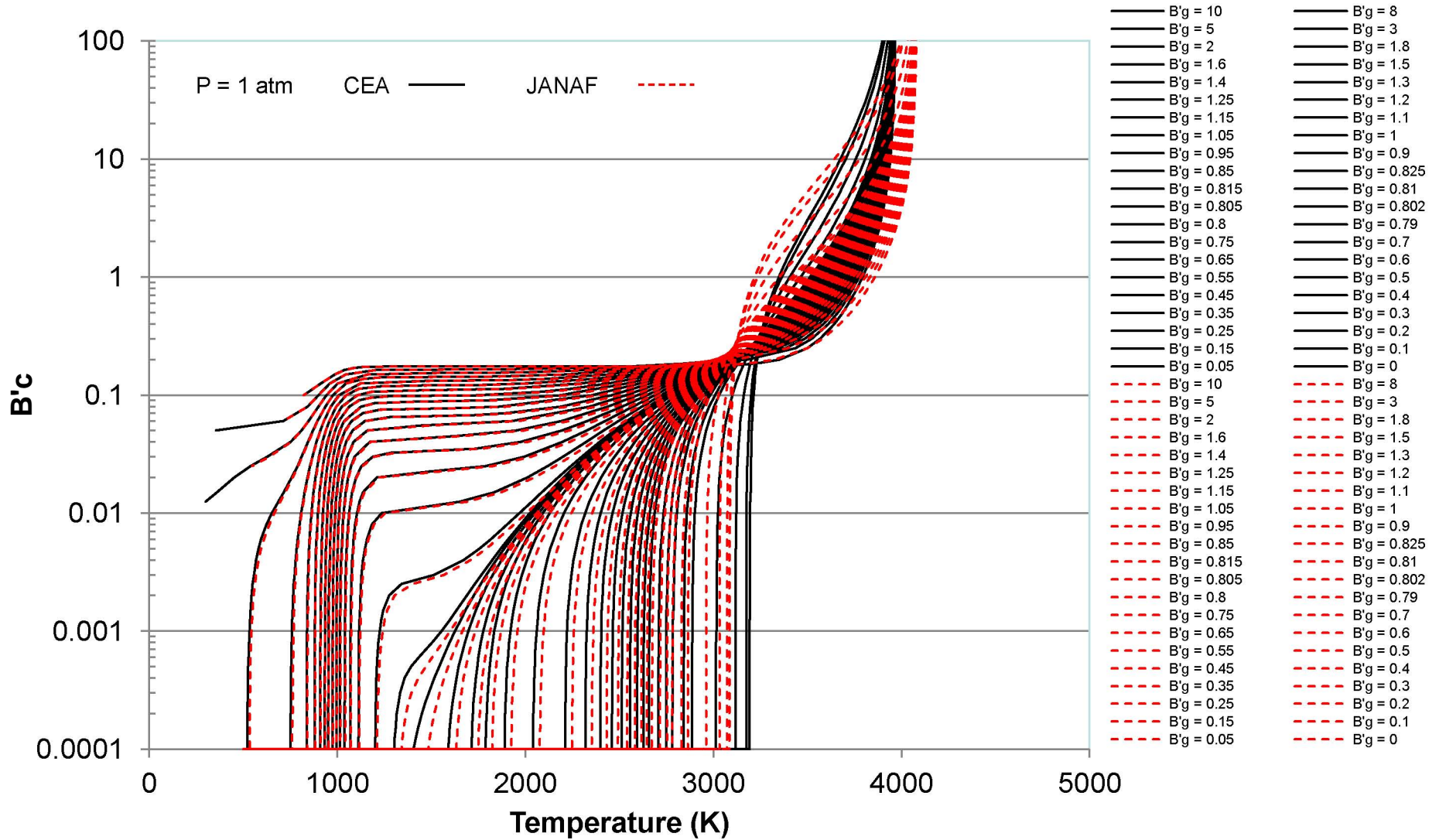


Mutation CEA versus ACE CEA - II



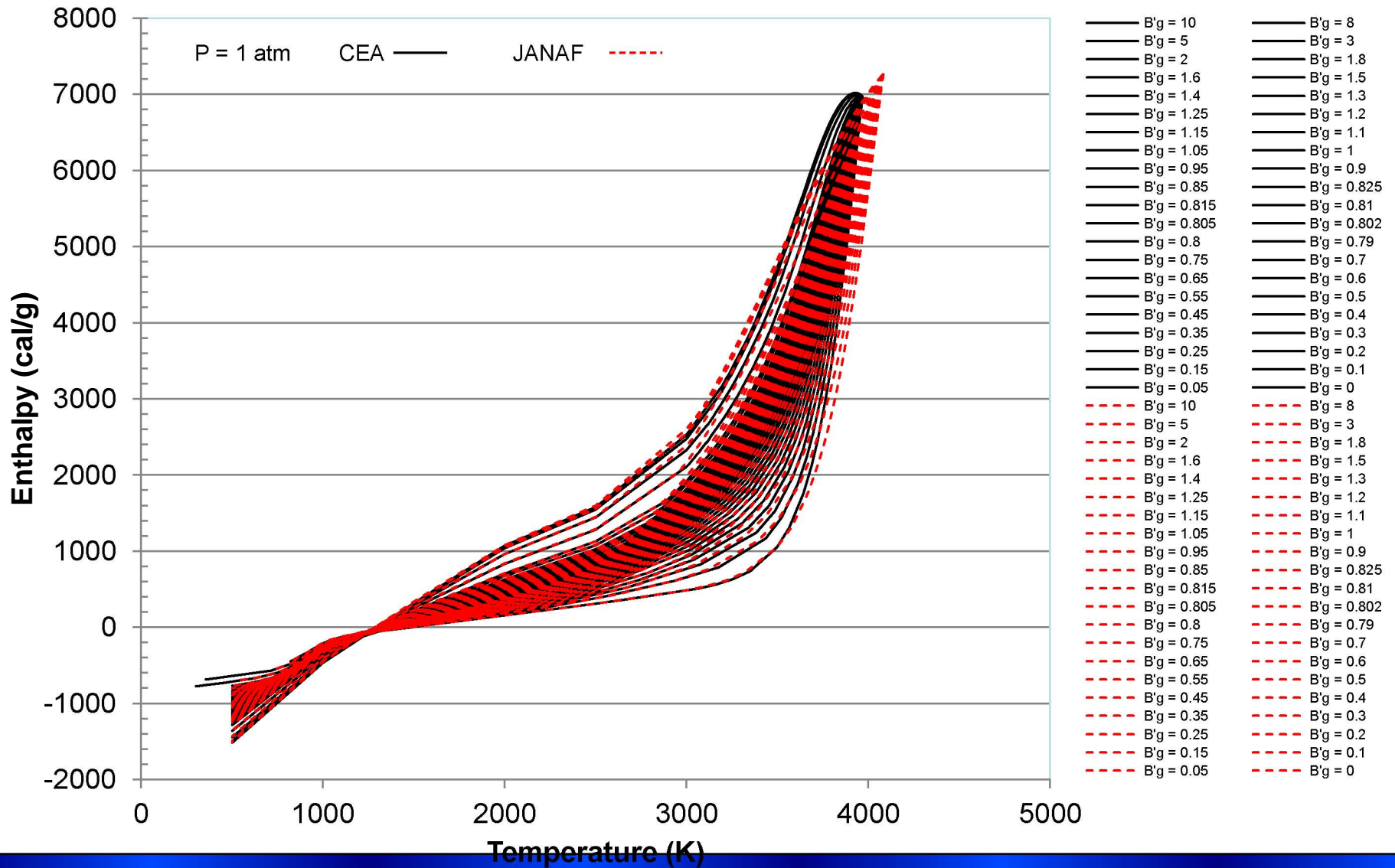


ACE CEA vs. JANAF Surface Thermochemistry - I



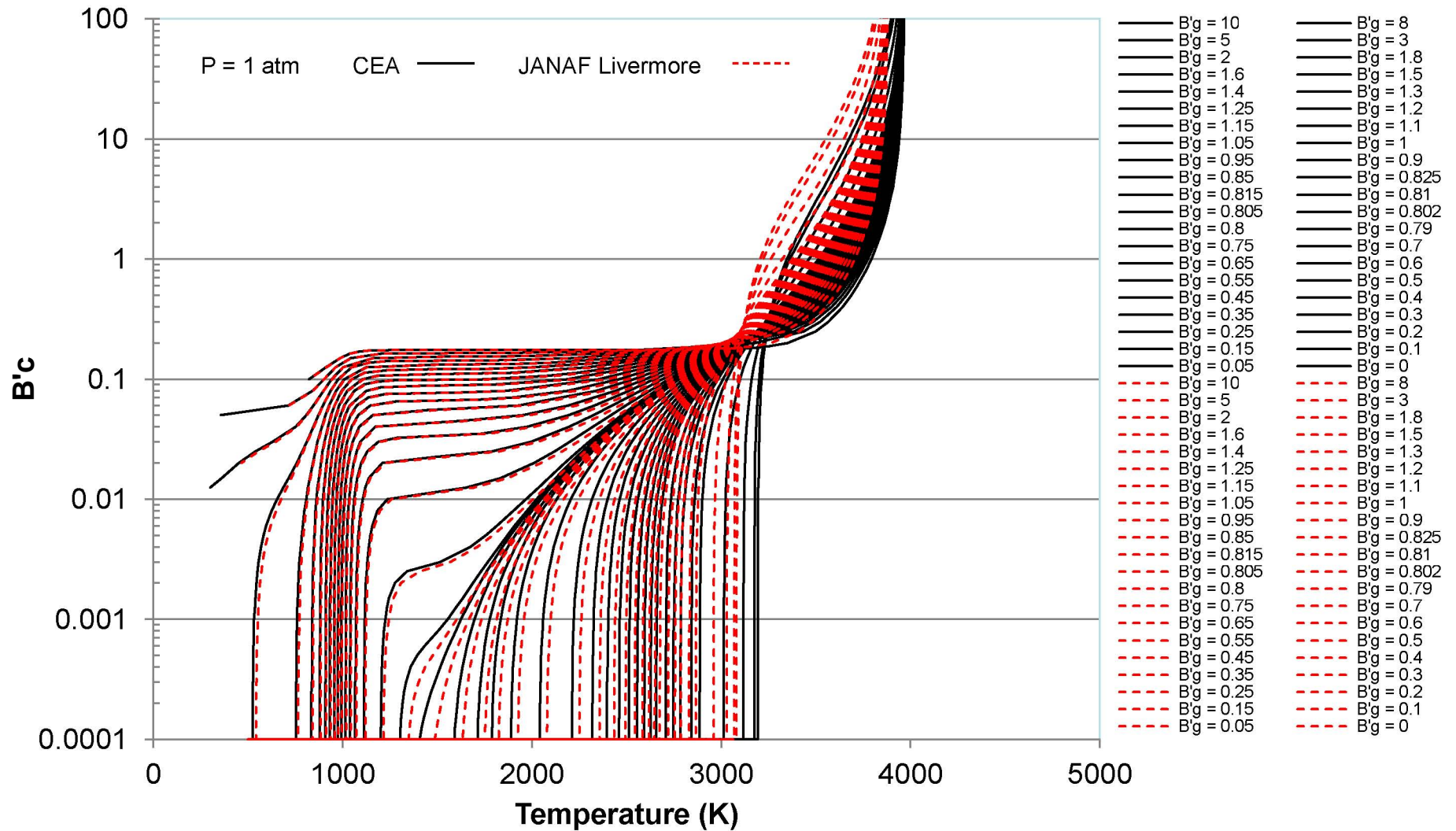


ACE CEA vs. JANAF Surface Thermochemistry - II



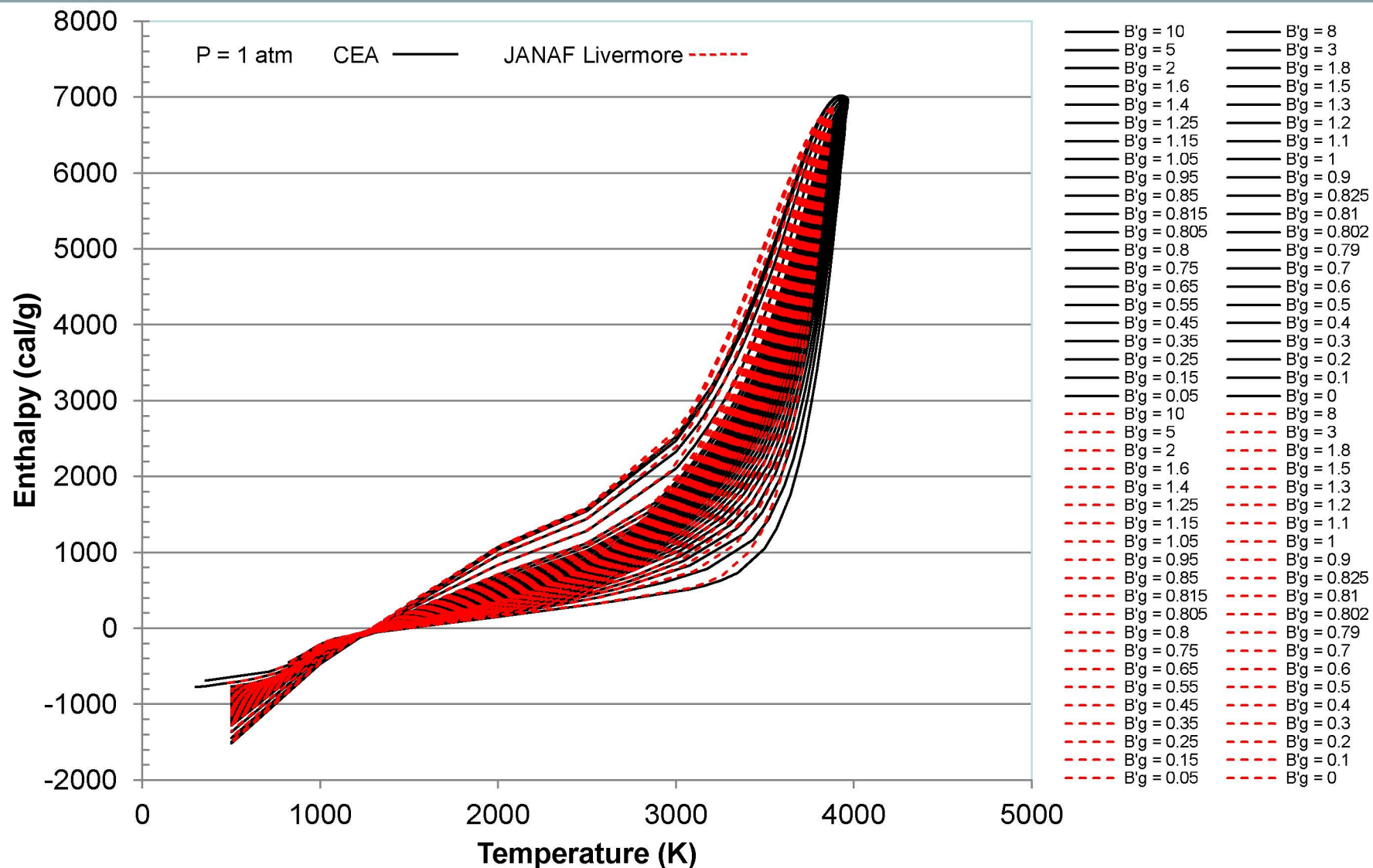


ACE CEA vs. JANAF – Livermore Thermochemistry - I



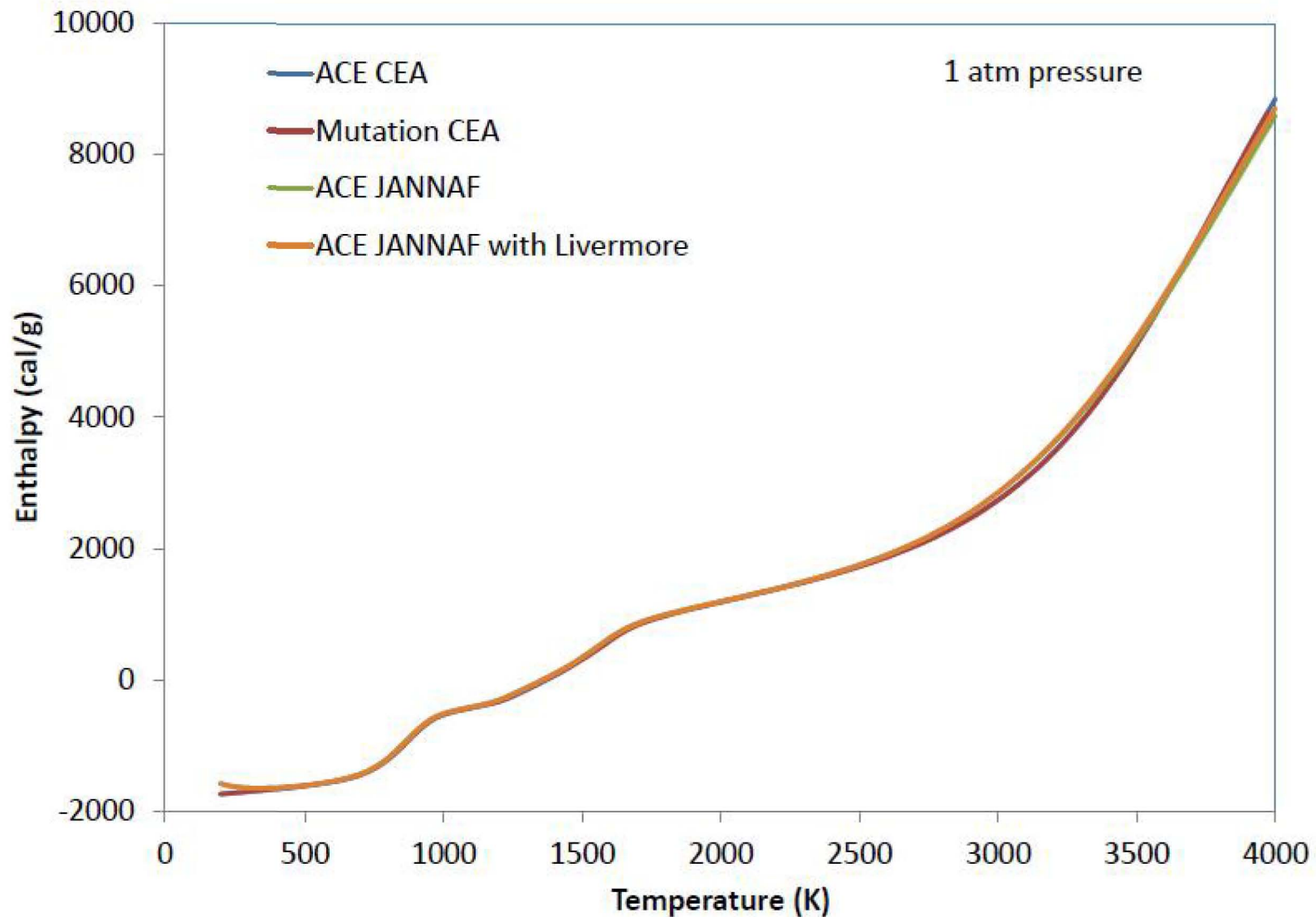


ACE CEA vs. JANAF Livermore Thermochemistry - II





Pyrolysis Gas Enthalpy





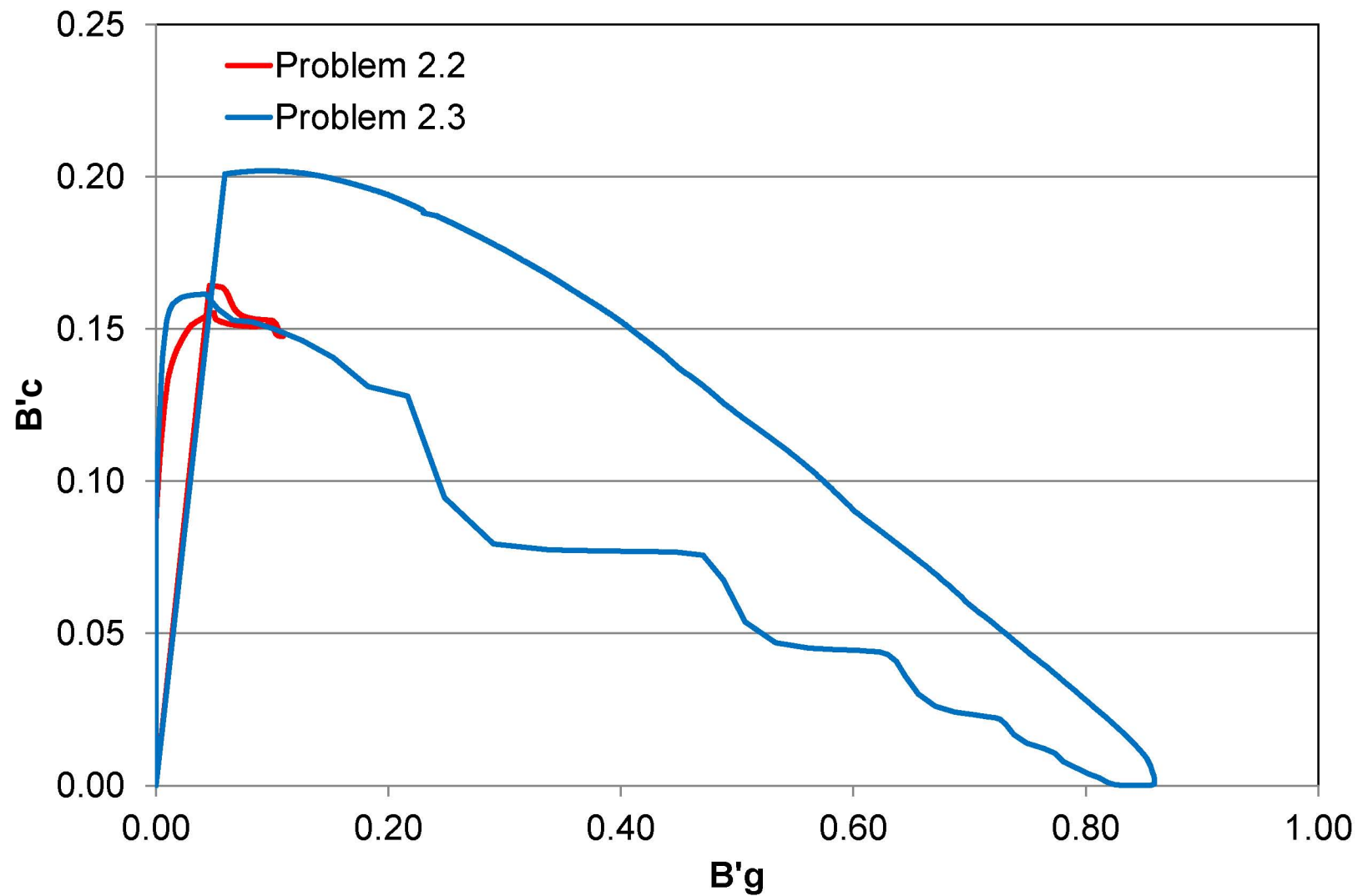
Observations



- Significant difference between Mutation CEA and ACE CEA
 - B'c, B'g and temperature profiles similar
 - Enthalpies exhibit significant difference in regions of low B'gs and high enthalpies
- Differences between CEA and JANAF models occur mainly in the vaporization regimes
- Sample problems traverse a limited range of thermochemical conditions
 - Problems do not traverse the vaporization regime where there are significant differences between CEA and JANAF models
 - Problems do not traverse into high B'gs where significant differences between Mutation CEA and ACE CEA occur
- No significant differences in pyrolysis gas enthalpy between all models
- Do not expect significant differences between thermochemical models for these test problems

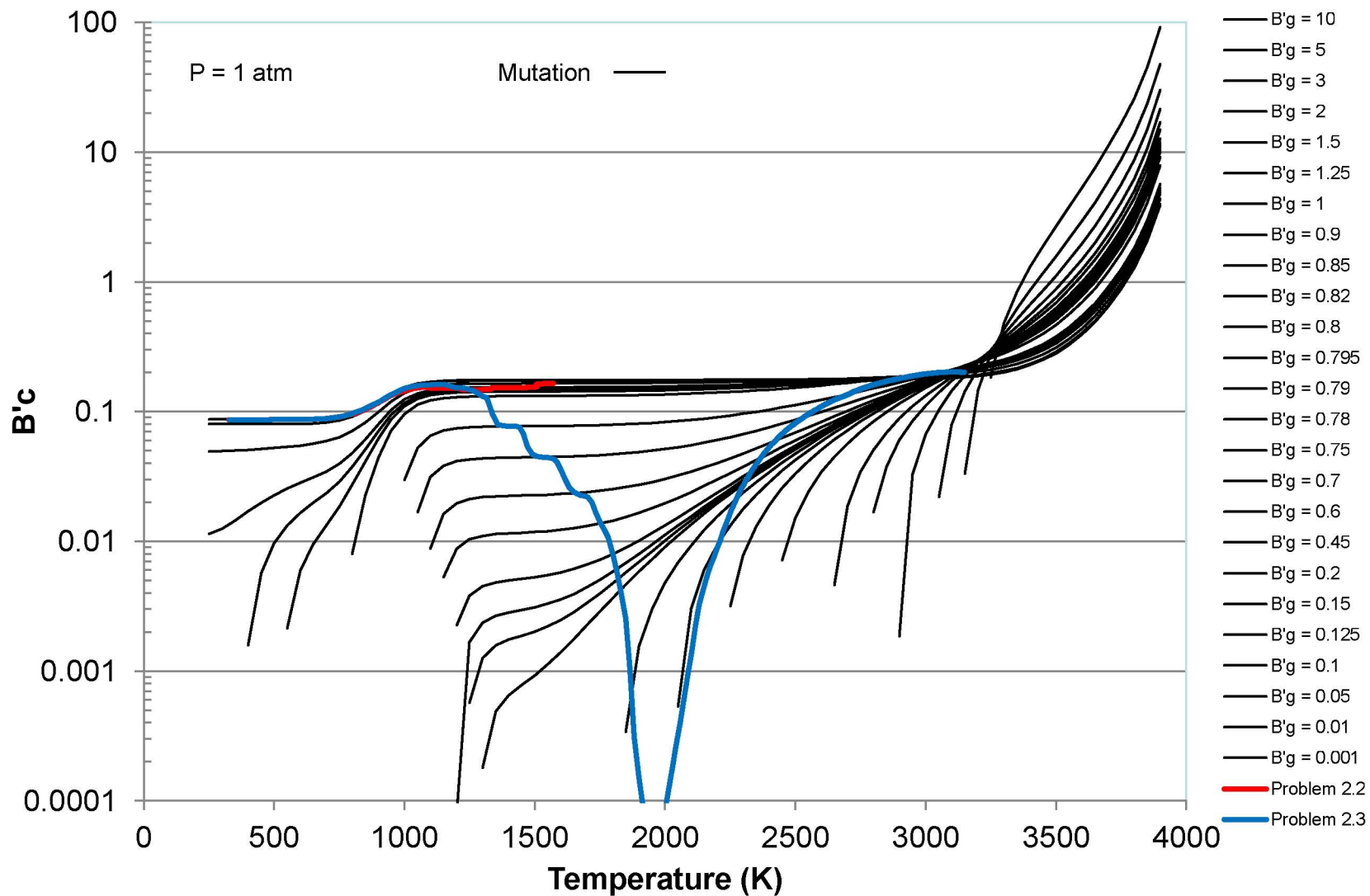


CMA Mutation CEA Surface State Trajectory - I



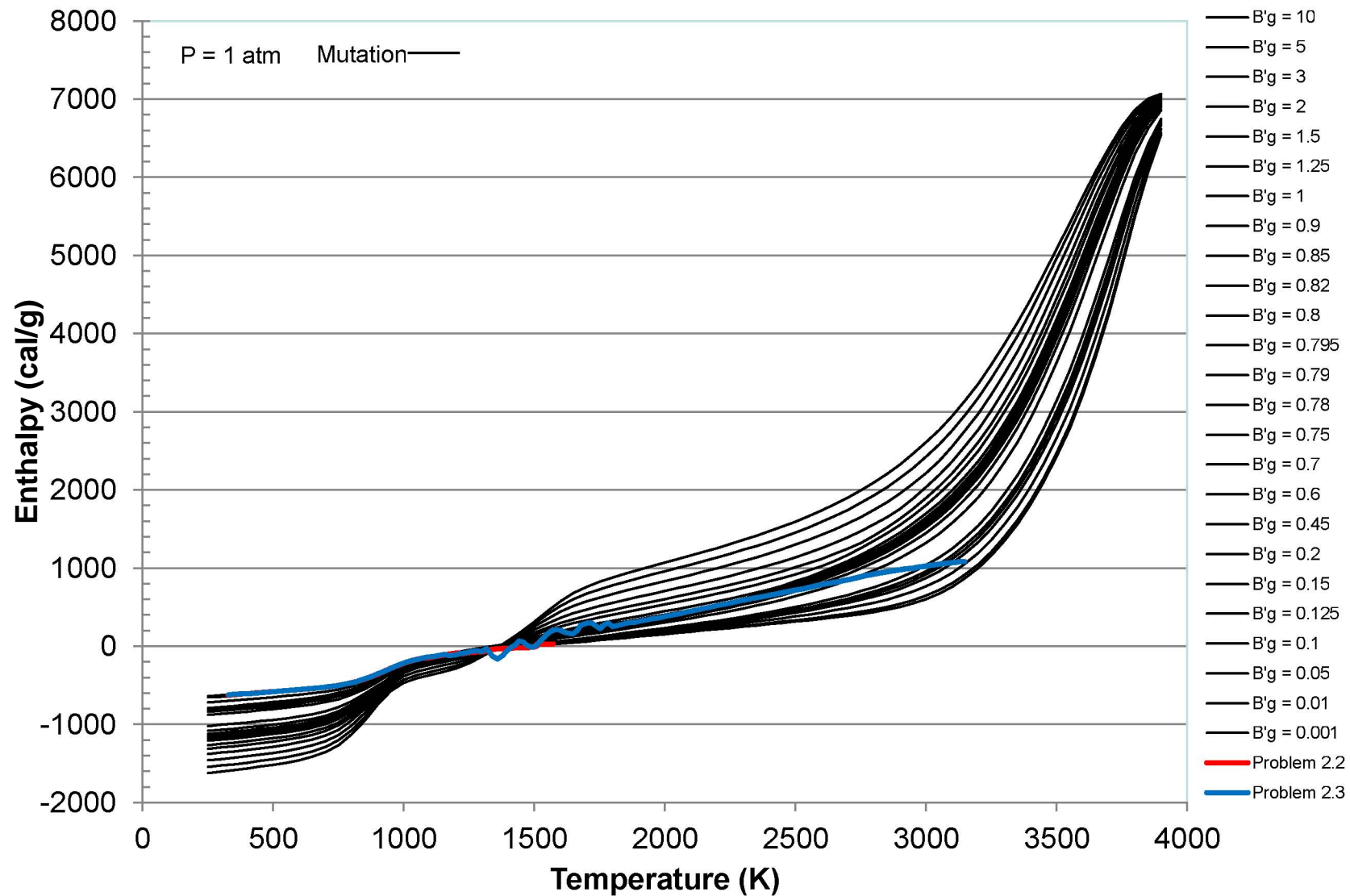


CMA Mutation CEA Surface State Trajectory - II



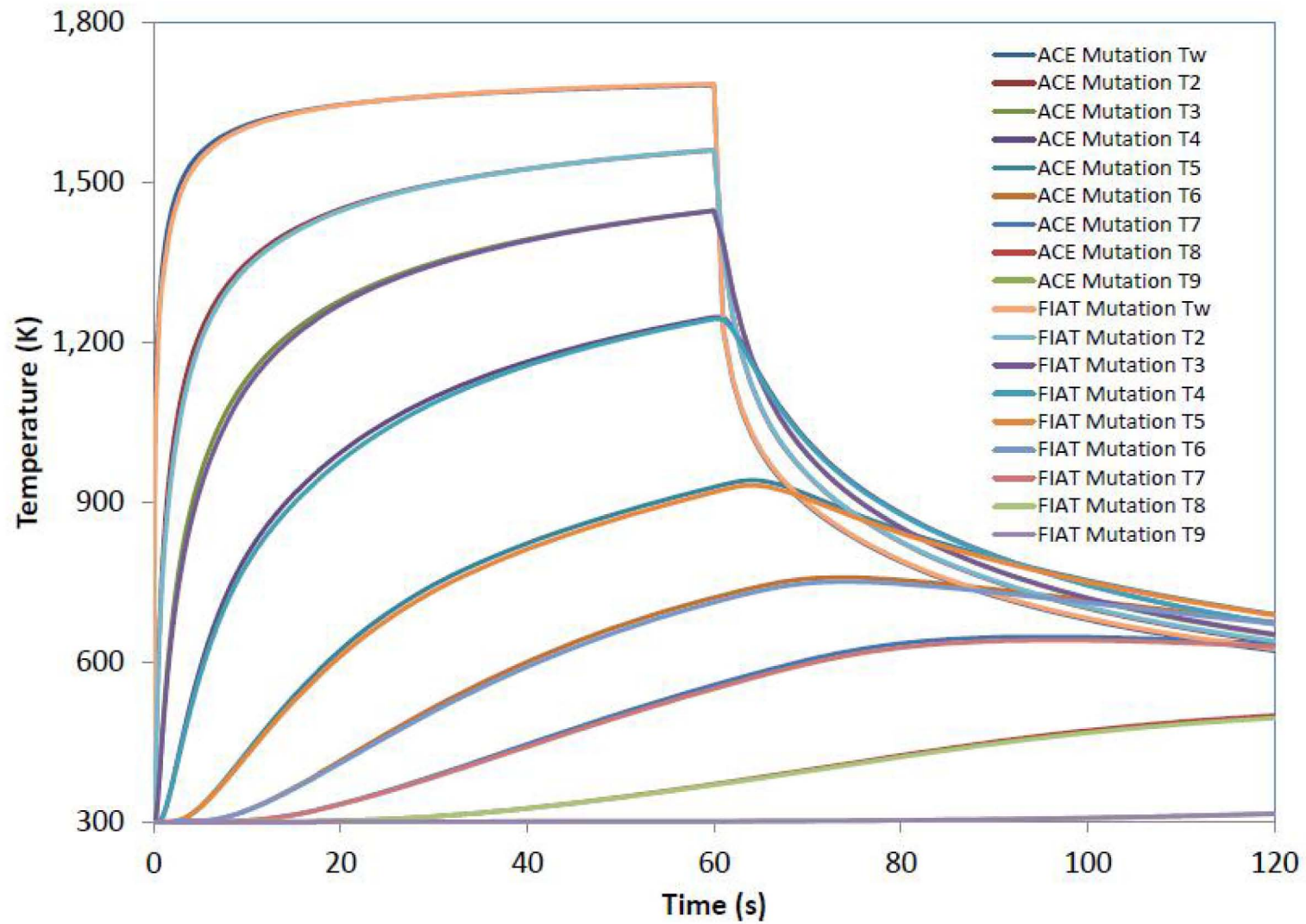


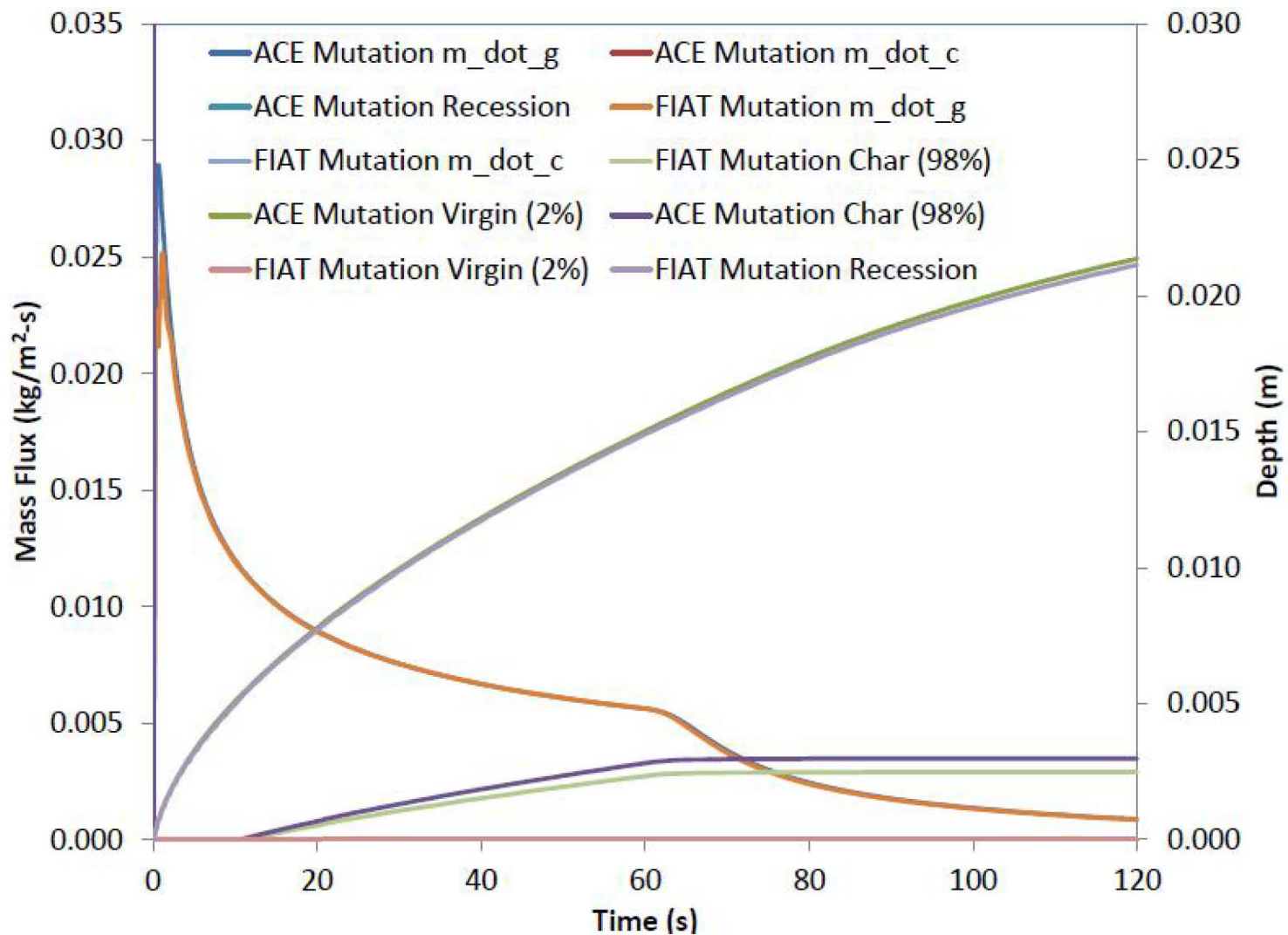
CMA Mutation CEA Surface State Trajectory - III





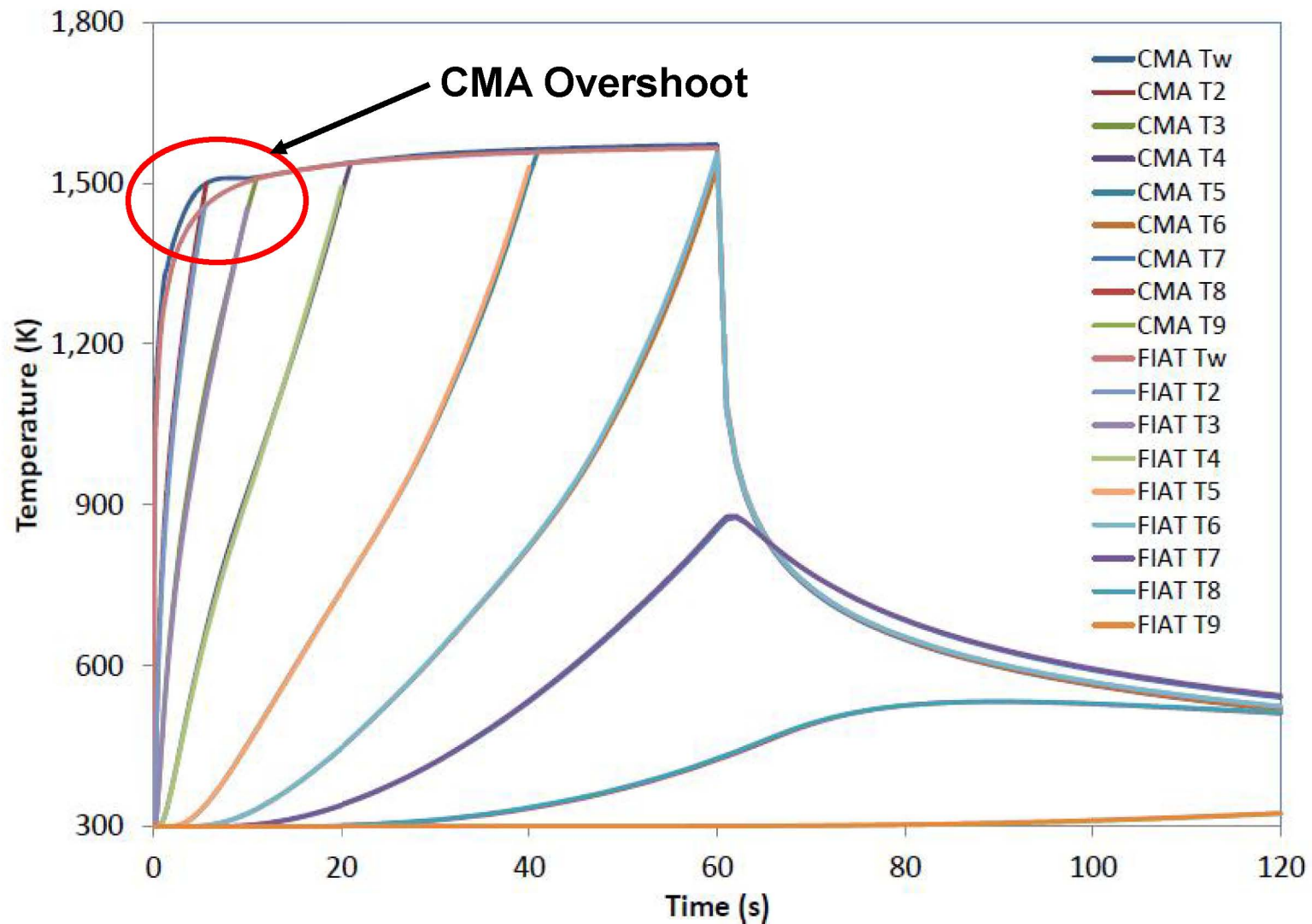
Problem 2.1 - CMA Mutation CEA Subset vs. FIAT Mutation CEA Subset - I





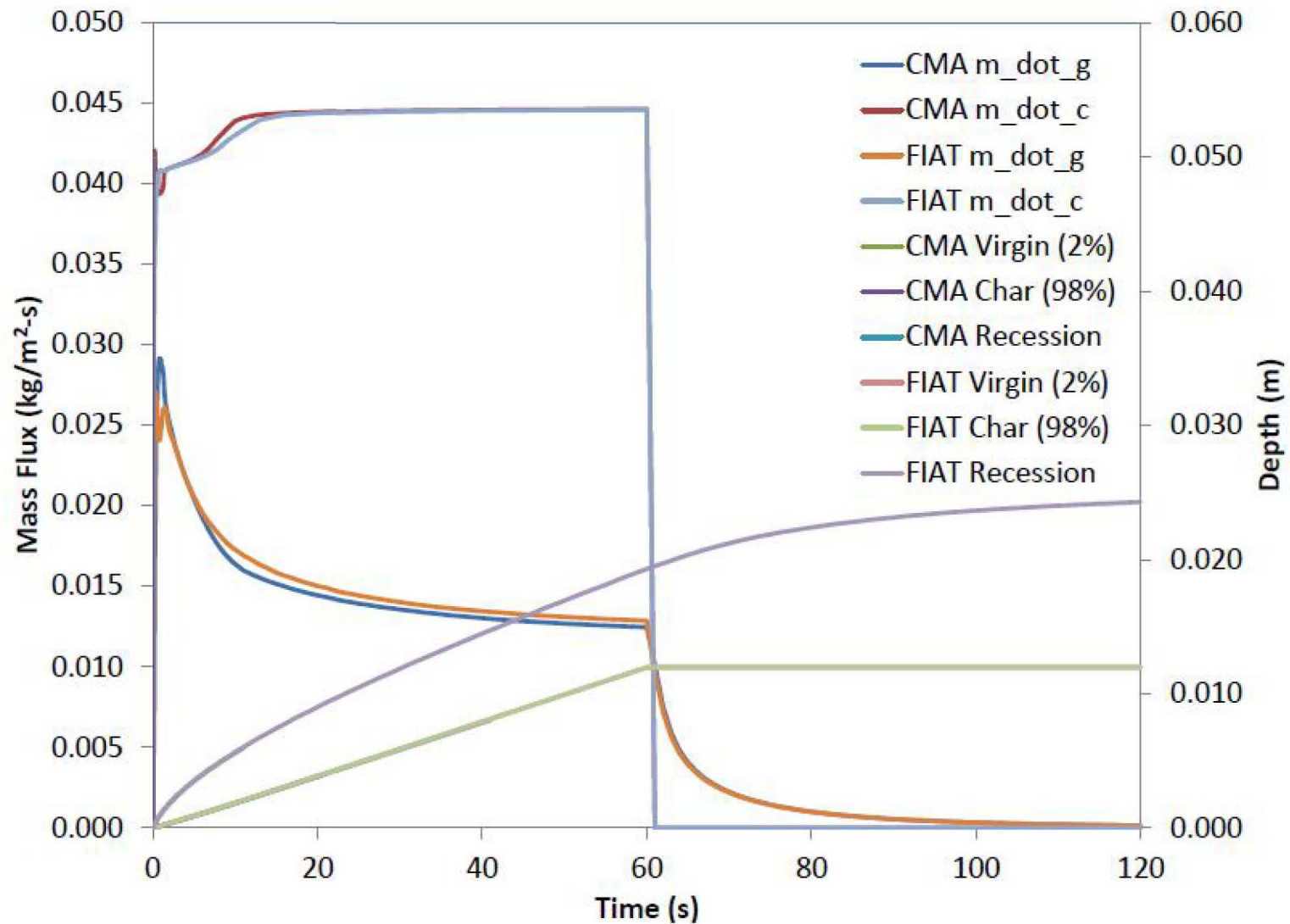


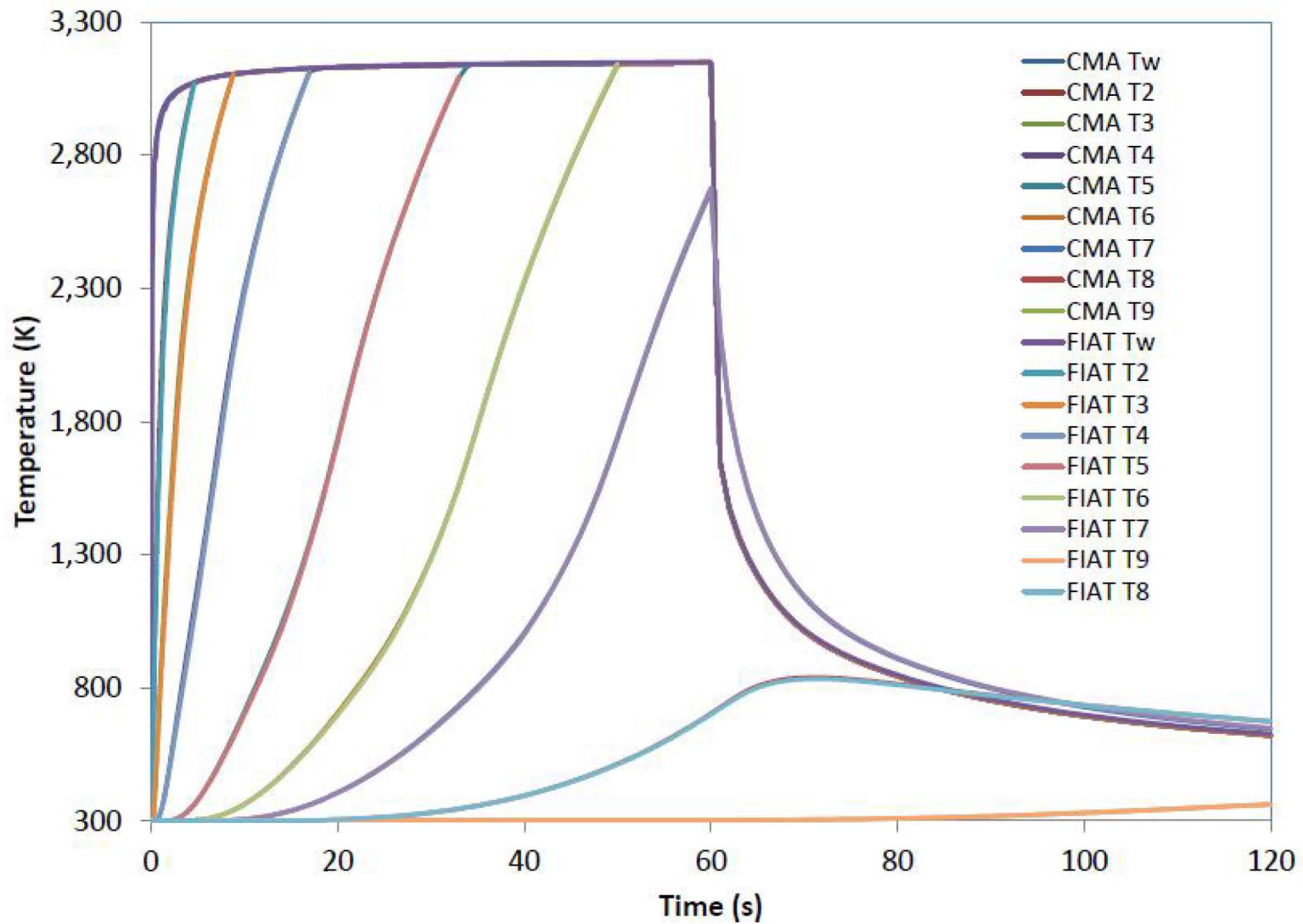
Problem 2.2 - Mutation CEA Subset CMA vs. FIAT - I





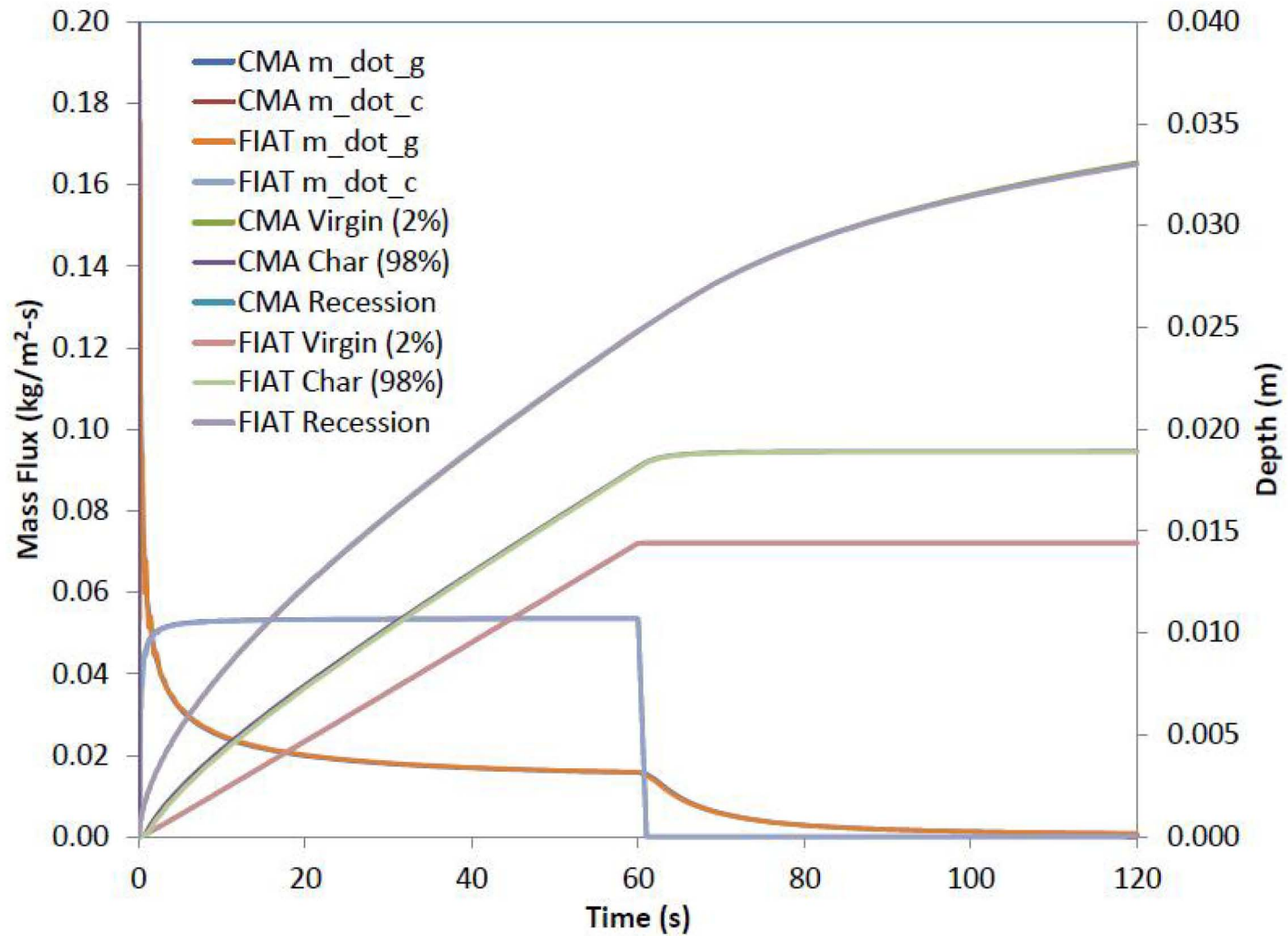
Problem 2.2 - Mutation CEA Subset CMA vs. FIAT - II





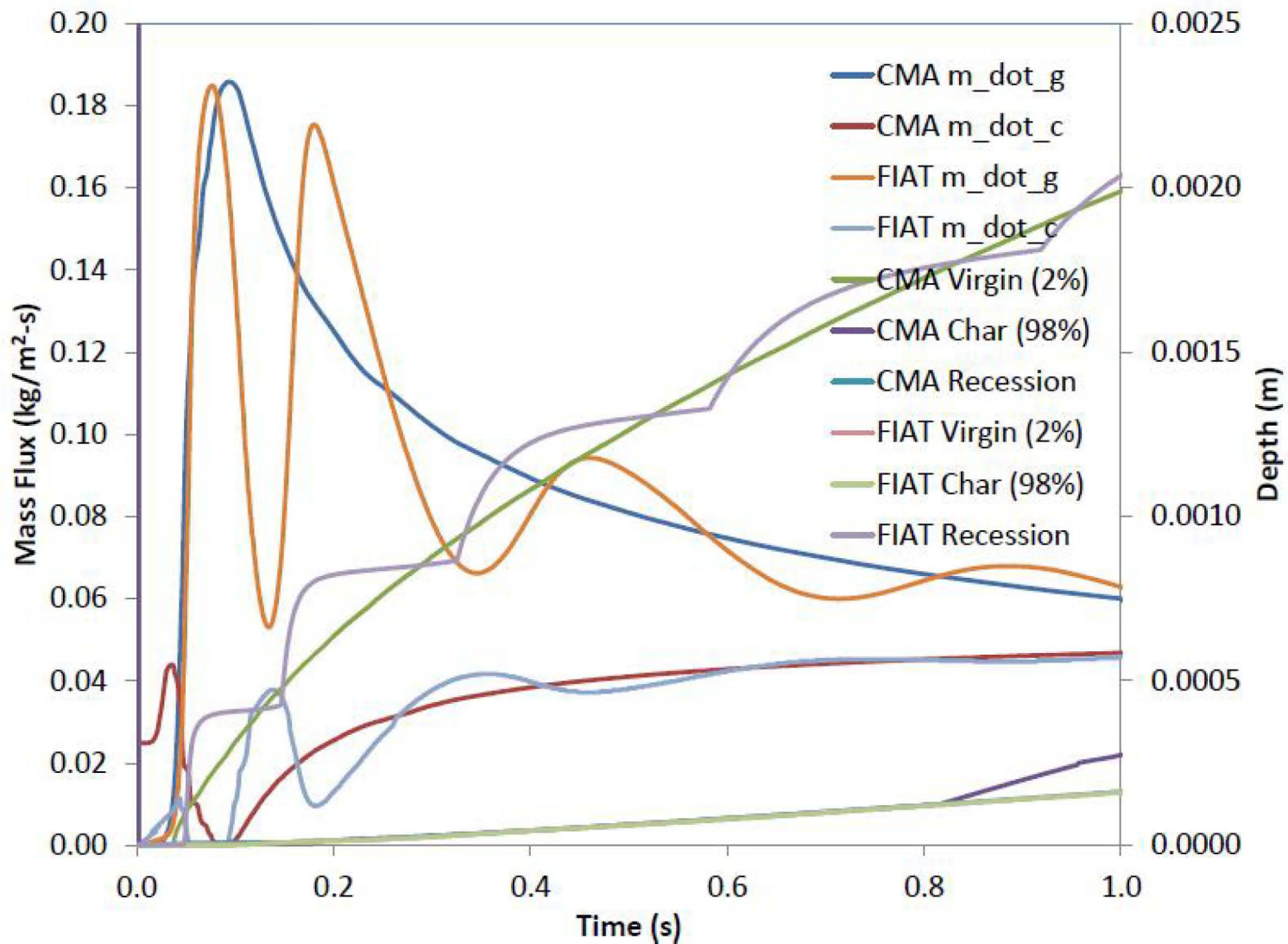


Problem 2.3 - CMA Mutation CEA Subset vs. FIAT Mutation CEA Subset - II



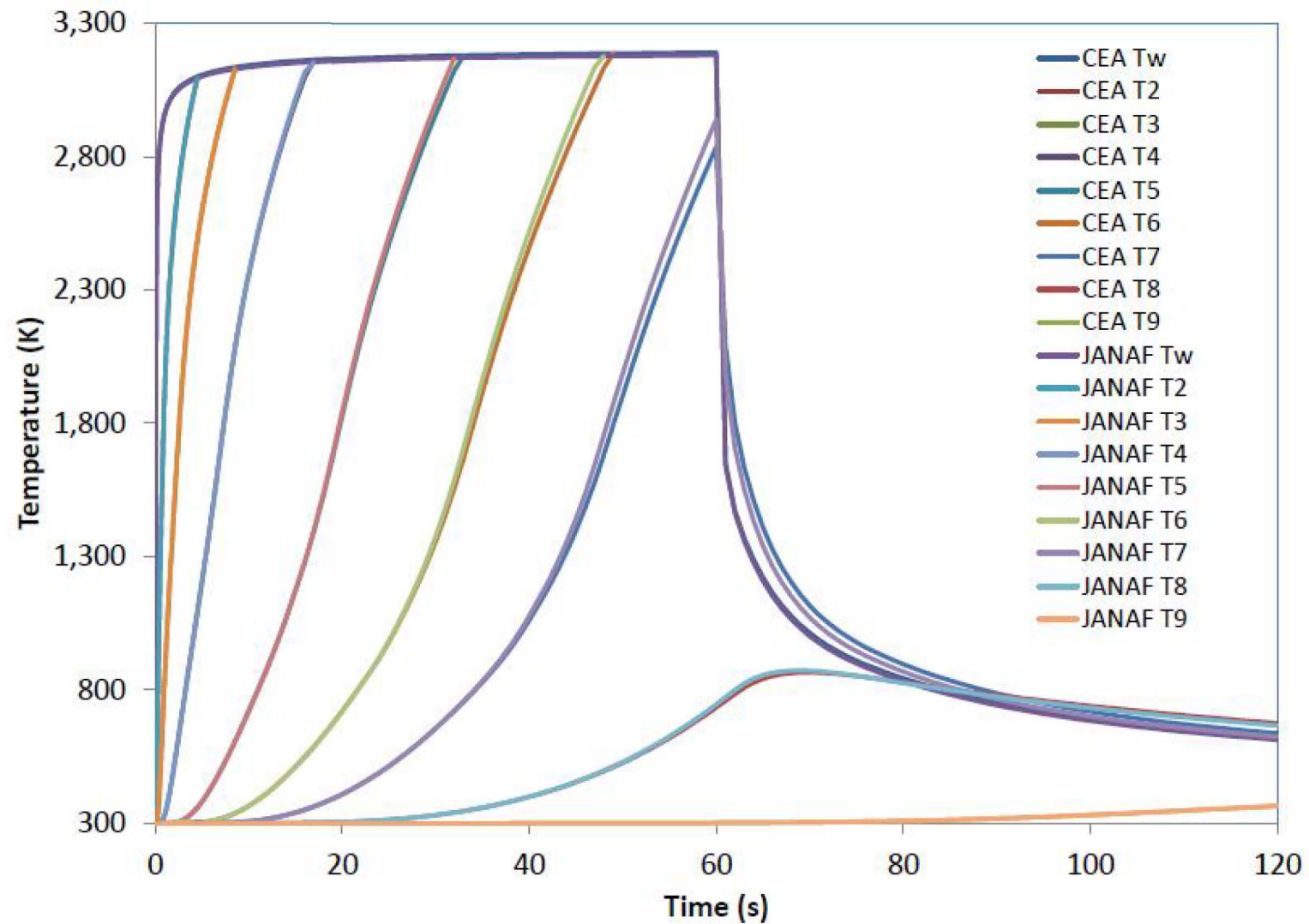


Problem 2.3 - CMA Mutation CEA Subset vs. FIAT Mutation CEA Subset - III



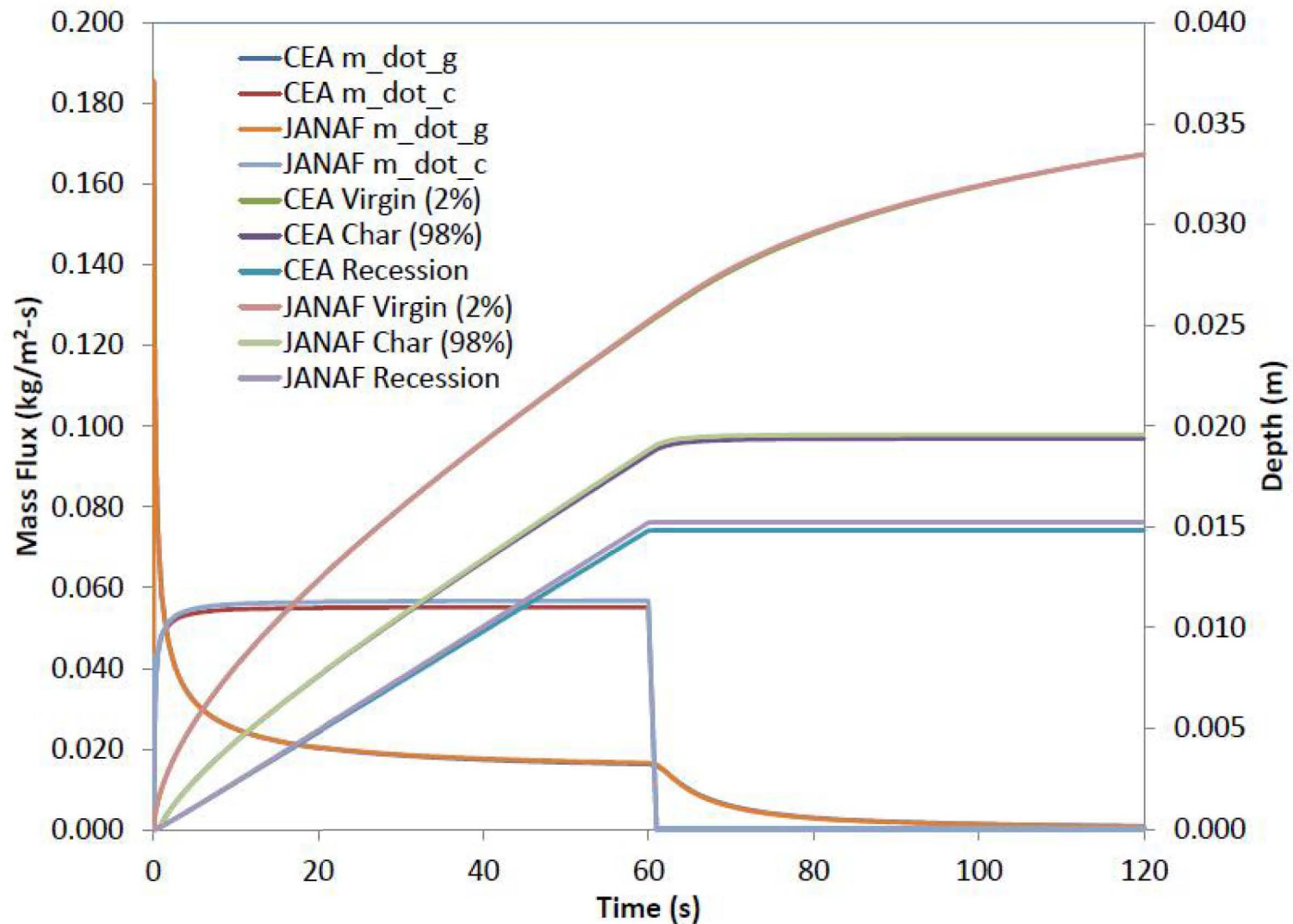


Problem 2.3 - CMA – ACE CEA vs. ACE JANAF - I



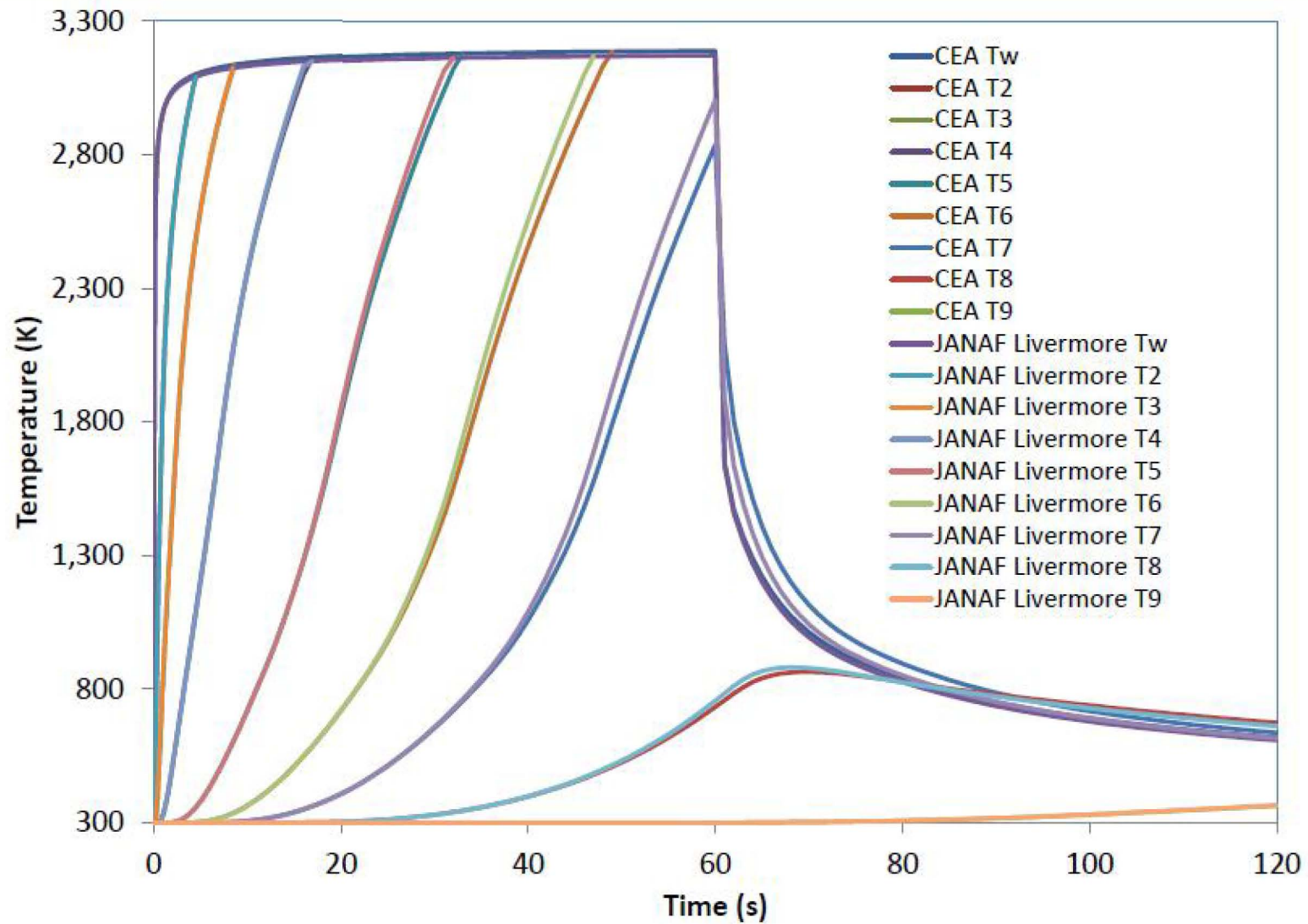


Problem 2.3 - CMA – ACE CEA vs. ACE JANAF - II



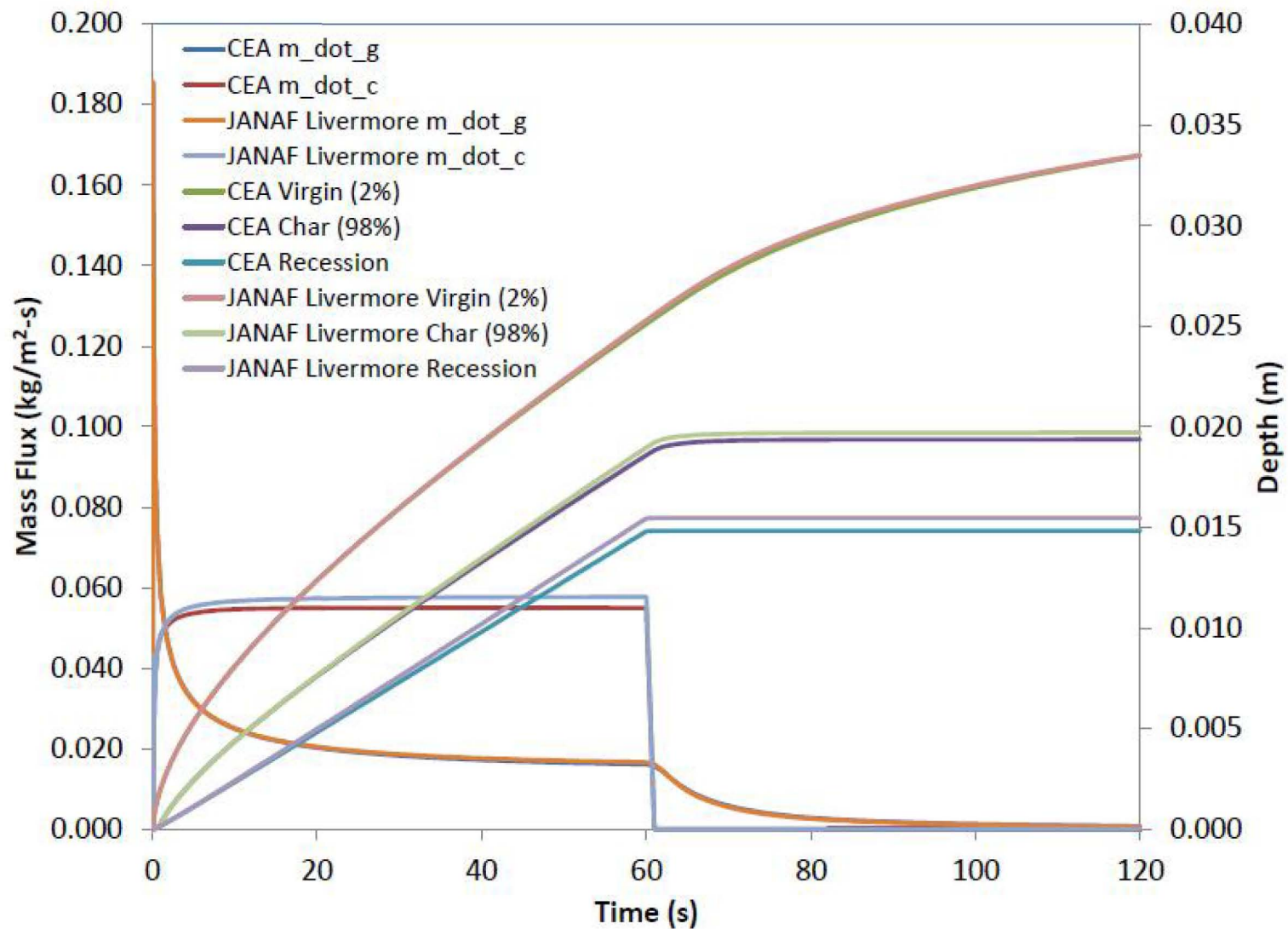


Problem 2.3 - CMA – ACE CEA vs. ACE JANAF Livermore - I





Problem 2.3 - CMA – ACE CEA vs. ACE JANAF Livermore - II





Final Observations



- CMA and FIAT exhibit excellent temperature and recession history agreement for Problems 2.1 and 2.3
- Agreement is excellent even with early-time oscillations in FIAT solution
- Small temperature overshoot observed by CMA compared to FIAT at early times for Problem 2.2
- Excellent recession history agreement between CMA & FIAT for Problem 2.2
- Small differences observed between all thermochemistry models
- Largest difference occurs between CEA and JANAF Livermore where JANAF Livermore recession is approximately 4% greater